Modeling and Simulation Architecture for the Effects of Sound on the Marine Environment (ESME)

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LONG-TERM GOALS

To help mitigate future potential impacts on marine mammals from sonar systems, the US Navy initiated the ESME program to explore the interaction between sound, the acoustic environment, and marine mammals. NRL was chosen by the Office of Naval Research (ONR) to be the systems integrator for the models and software developed by the government, industry, and academic researchers that comprise the ESME team.

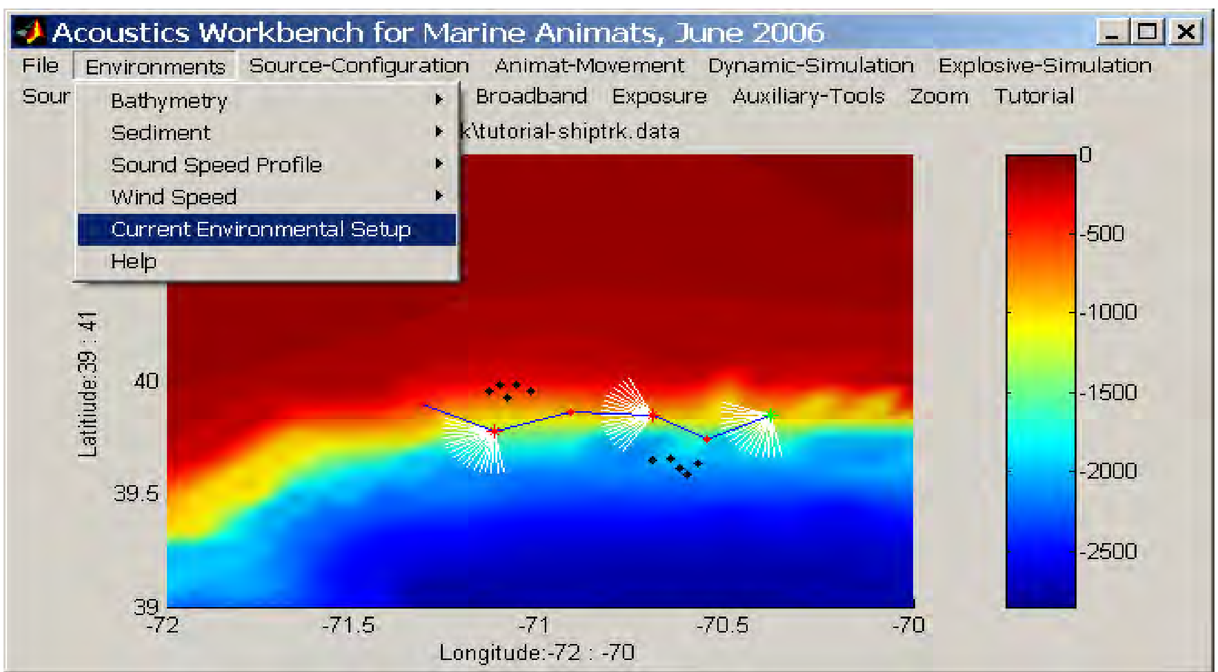

Figure 1. The revised ESME workbench main menu, displaying bathymetry from the Mid-Atlantic Bight area. A simulated ship tracks and beam patterns are shown. The 'diamond' icons represent the animats.

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OBJECTIVES

Our objective was to build and test an underwater risk model for estimating the cumulative acoustic exposure along an animal's track. (A simulated marine mammal will be referred to as an *animat*.) The resulting system, referred to as the ESME software workbench, integrates data sets and computer models contributed by ESME collaborators in the areas of oceanography, underwater acoustic propagation, and marine mammal physiology and behavior. The ESME software workbench must accurately model the complete sound propagation path: from the source, through the medium, and to the biosensor system. Several different models for acoustic exposure are provided, including two provisional models for predicting the occurrence of *temporary threshold shifts* (TTSs). The TTS models require the received acoustic waveform (i.e. time-series) as an input, and the time-series can be computed at each point along an animat's simulated three-dimensional track. For computationally intensive simulations involving moving platforms, and long simulated periods of time (e.g. hours rather than seconds), either the instantaneous or cumulative acoustic energy (dB re 1 μPascal^2-second) is estimated for each animat, rather than the received acoustic time series.

APPROACH

The software modules and data contributed by ESME co-investigators were incorporated into a MATLAB workbench that transparently integrates the modules, and provides an intuitive menu-driven interface for the user. Mr. Haw-Jye Shyu was the primary developer of the workbench, with technical support from Dr. Roger Hillson. Our ESME co-investigators are listed in Table 1.

Table 1 – Deliverables from ESME team members

Contributor	Organization	Module	Programming Language
Haw-Jye Shyu, David Armoza, Roger Hillson	Naval Research Laboratory	ESME MATLAB workbench development and system integration.	MATLAB and Visual C++
Mike Porter, Martin Siderius	Heat, Light, and Sound Research Inc.	Acoustic propagation loss (Bellhop, Kraken), and received time series generator.	FORTRAN and MATLAB
David Mountain, Allyn Hubbard	Boston University	Mammalian auditory system model. Requires received time series as input.	MATLAB.
Darlene Ketten	WHOI/Harvard Medical School	Parameters for the Boston University auditory model.	Text
Jim Miller, Gopu Potty	University of Rhode Island	Geoacoustic and sediment models.	MATLAB
James Finneran	SPAWAR	Temporary Threshold Shift (TTS) estimation functions. Requires received time series as input.	MATLAB
Dorian Houser and Matt Cross	Biomimetics, Inc.	Marine mammal movement models.	Visual C++

Glen Gawarkiewicz, Chris Linder	Woods Hole Oceanographic Institution (WHOI)	Sound speed profile data.	Text format

WORK COMPLETED

Model Development and Integration: During the preliminary phases of this project, NRL analyzed and integrated acoustic propagation models, sound speed profiles, bathymetric models, geo-acoustic models, and temporary threshold shift models provided by other members of the ESME team (see Table 1). During this period of performance, additional models and capabilities have been added. For example, a Dynamic Simulation model was developed to simulate the complex aversive behavior of animats responding to the received sound energy. A commercial installer was used to greatly simplify installation of the workbench, Audio-Visual tutorials were written and implemented, and integrated models for underwater explosions were added. A limitation on the number of permissible animats was corrected.

RESULTS

The ESME workbench provides an open architecture for model integration. The workbench integrates diverse software components received from scientists with established domain expertise. The system runs on an inexpensive PC windows system, and has a menu-driven user-interface. The workbench is operated through a combination of pull-down and mouse-selected menus. Using these menus allows the user to set desired parameters within different menu fields, and to save and retrieve parameterized scenarios. The results of the simulations can be displayed graphically (Figures 1-3). At ONR's direction, we used this approach to model selected Naval exercises.

Features added during FY06 (through 30 Sept 06) include:

- The Auto-installer for the ESME Workbench is complete (NRL: Segaria, Shyu, Hillson) (Figure 4).
- To speed up the software installation, the ESME data sets are separated from the workbench software.
- Added “Help Message” for major main menus.
- Added “Current Status” summary for the main menus.
- Added integrated models for simulating explosive charges, with supporting software provided by Gopu Potty. The workbench can now be used to simulate the underwater noise exposure that can occur during naval exercises in which underwater explosive charges are deployed. Given the weight and the detonation depth of the charges, the explosive charges firing patterns are modeled as a combination of a specified spatial distribution and a specified temporal sequence. (In prior versions of the workbench, REFMS (Reflection and Refraction in Multi-Layered Ocean/Ocean Bottoms with Shear Wave Effects) was used to simulate the propagation of shock waves from an underwater charge. REFMS was run in a stand-alone mode, and was never fully integrated into the ESME workbench.)

- Added the capability to convert depth, salinity, and temperature data into a sound speed profile (suggested by Scott Harper, with supporting software provided by Gopu Potty).
- Added nine Audio-Visual tutorials. These are incorporated into the workbench, and can be executed from the menu.
- With the assistance of a SEAP student, developed a prototype tool to extract cetacean diving parameters from raw track data.
- Successfully integrated Biomimetica's latest Behavior and Movement Model (aka 3MB) (Figure 5).

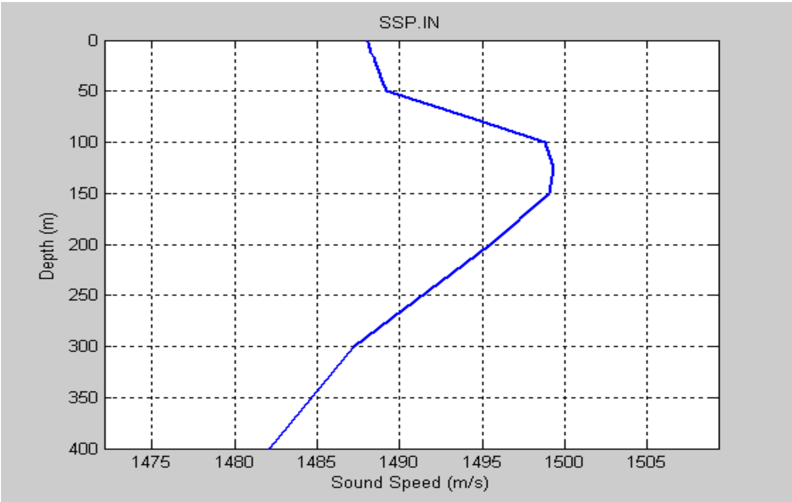

Figure 2a. A winter sound speed profile for the Mid-Atlantic bight test site. Depth is in meters and sound speed in meters/sec.

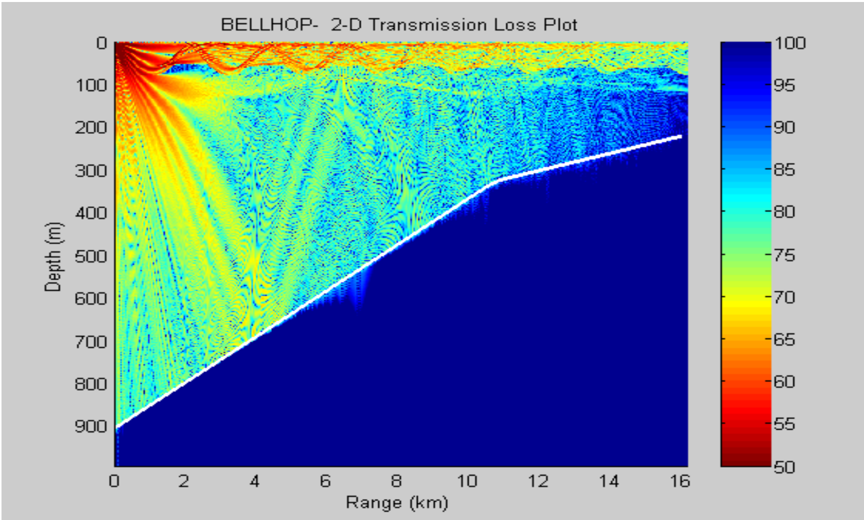

Figure 2b. A 2-d transmission loss plot generated using the sound speed profile shown in Figure 2a, illustrating simulated beamforming.

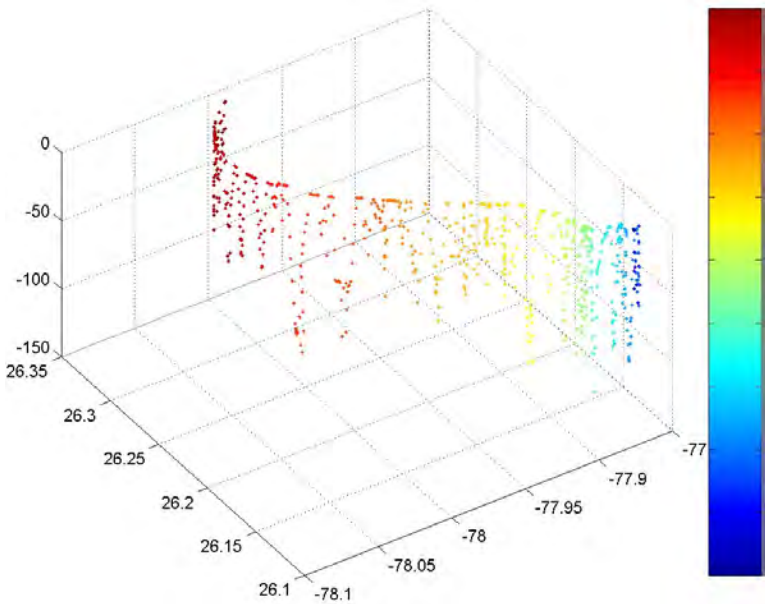

Figure 3. A track for a simulated marine mammal ("animat"). Latitude ranges from 26.1 to 26.35 degrees, and longitude from -77 to -78.1 degrees.

Figure 4. The ESME Setup Window.

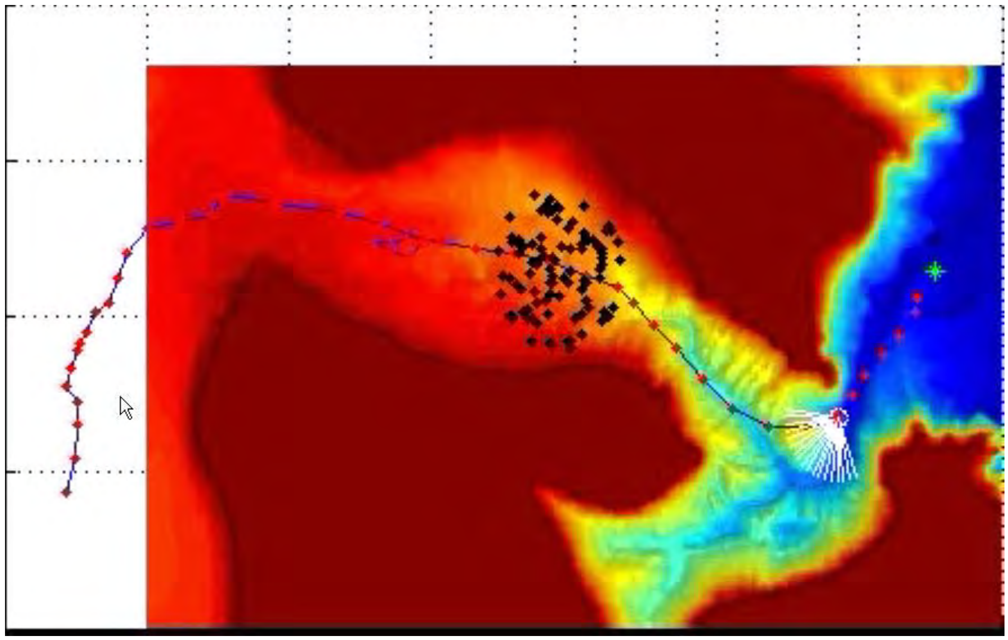

Figure 5a – The beginning of a simulated 10-hour ship run. There are 100 animats randomly distributed at the center of the Providence Channel of the Northern Bahamas Islands. The aversive behavior model is enabled, and the animats are programmed to move away from the acoustic source.

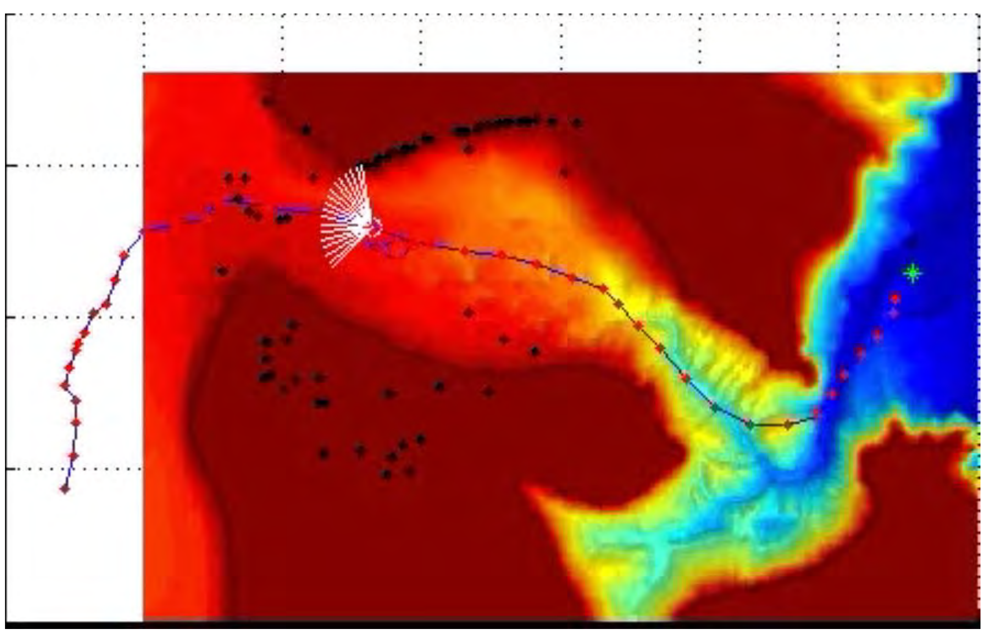

Figure 5b – The last frame of the simulation. The entire sequence of events was also captured in an optional movie.

IMPACT/APPLICATIONS

There are two major users of the dynamic ocean environment. The first, the Navy Warfare Development Center (NWDC), is charged with testing implications of new technology on naval doctrine and tactics. The second, the Joint Training and Simulation Center, is charged with experimentation at the joint level. The architecture work that we are pursuing will provide a viable undersea and coastal environmental model in which impacts to sensors and systems (biological and otherwise) can be assessed.

TRANSITIONS

Haw-Jye Shyu traveled to Boston University (BU) to teach a group of auditory researchers about the software architecture of the ESME workbench, and how the workbench is actually used. The BU group is planning on developing extensions that can be added on the workbench. Using the modeling and simulation techniques for the underwater charge simulation, we simulated a scenario similar to a Navy VAST (Virtual At-Sea Training) exercise. These results were delivered in a timely fashion to ONR. The paper "A Software Workbench for Estimating the Effects of Cumulative Sound Exposure in Marine Mammals", by Haw-Jye Shyu and Roger Hillson, was published in a special issue of the *IEEE Journal of Oceanic Engineering* (JAN 06). This paper provides a progress report through late 2003 on the ESME software workbench.

RELATED PROJECTS

We continue to work closely with NRL investigators to support the environmental modeling for large scale distributed training exercises. Beginning in July 2004, collaboration with Woods Hole Institute, Boston University and NRL commenced. This new start, funded by the NOPP (National Oceanographic Partnership Program), was to use advanced visualization techniques to model the auditory processes of cetaceans. This effort continued in FY06, resulting in improved anatomical visualization techniques demonstrated in both NRL's four-surface immersive environment, and on a high-resolution six-tile wall display. Common display software is now running on both display systems.

Haw-Jye Shyu, with assistance from Roger Hillson, mentored a SEAP student in the summer of 2006. The research effort was to develop a software tool that could be used to automatically extract a set of diving parameters from an empirical diving profile for a marine mammal. A report on this effort was submitted to ONR (ref. 3).

REFERENCES

1. Shyu, H-J., and R. Hillson, "*The ESME Workbench Status*," presentation, ESME meetings 27-28 Oct 2005.

2. Shyu, H-J., "*Status of the ESME Workbench*", 8 June 2006, ESME meeting (ASA meeting Providence, RI).

3. Son, Gregory, "*Automatically Extracting Diving Parameters from a Digitally Recorded Marine Animal Diving Profile*", SEAP report, 7 August 2006. Submitted to Robert Gisiner by email on 18 October 2006.

PUBLICATIONS

1. Hillson, R., and H-J. Shyu, "Anthropogenic Noise and the Marine Environment", *2006 NRL Review*, in press.

2. Shyu, H-J., and R. Hillson, "A Software Workbench for Estimating the Effects of Cumulative Sound Exposure in Marine Mammals", *IEEE Journal of Oceanic Engineering*, Vol. 31, No. 1, January 2006.